fashion they are sure to do) from right and left, the bird can take advantage of their alternation to rise higher and higher, or at least to remain floating, without more effort than that which is required to give the due slope to its wings to make the most of every gust.

Next suppose the whole air with its two alternate opposite currents (as above) to be travelling horizontally in the same direction as one of the two opposite currents. Whether this supposition represents a possible state of things I hardly know, but it would correspond in some measure with the commonly observed phenomenon of a succession of alternate gusts and lulls in the wind. Under these conditions, if the air-movement be all horizontal, it is difficult to see how the bird can turn the alternate gusts to advantage, unless it can alternate its own direction accordingly, stemming the gust and wheeling round to fall back with the lull. The bird then would either circle or would follow a wavy course oblique to the direction of the wind. But I imagine that alternate gusts and lulls (as felt, say, at the top of an observatory) are generally caused by a succession of vortices, of which only one phase at a time is present to the observer. These vortices will be infinitely various in the direction of their axes and currents, and it is useless to try and imagine their relative positions. Probably the sea-birds, with their æons of inherited experience, have acquired an instinctive perception of the probable sequences and correlations of air-streams and air-swirls, and are thereby guided so to steer their course, selecting the upward and avoiding the downward currents, as to gain the greatest possible advantage of lifting force that those currents can afford, to the great economy of their muscular strength, which would otherwise have to be spent in the labour of the wing.

In reading of the way in which albatrosses and other large sea birds will follow a ship at sea with little or no flapping of the wings, it has occurred to me that the great obstacle which the ship herself offers to the wind must of necessity give the wind an upward throw and originate a vortex in the air, possibly large enough and persistent enough to be useful to the birds. If the ship be a steamer, the drift of smoke from the funnel will indicate approximately the path of the retiring vortex. It is long since I have had any opportunity of observing, but I well recollect that the gulls used often to be seen in close relation to the smoke that drifted to leeward of the steamer. It is true that any chance morsels of biscuit, &c., thrown from the steamer would probably be thrown to leeward, and this might help to determine the position of the expectant gull.

Again, at sea, the ocean waves themselves, such as roll in from the Atlantic to the Land's End, must throw the wind into rolling vortices, which would afford slant upward currents. The slant, though very flat, might well be sufficient for the purpose of support to the long-winged sea-birds that know how to use it.

On land, countless obstacles impede the lower wind and tend to throw the air into a roll.

Bearing in mind, then, the perpetual variation in strength and direction of current in a high wind, the whirls and gusts, and veering flaws, and seeing how it is possible for the bird to utilise every such variation (except a downward current) to the purpose of its bodily support, we may, I think, obtain some insight into the agency whereby the birds accomplish their marvellous feats of soaring and sailing, upborne upon stiff-strained, motionless wings.

Further observations however are required for the full solution of the problem which I have here only tentatively approached. HUBERT AIRY

Woodbridge, February 28

SOME POINTS IN ELECTRIC LIGHTING[1]

THE science of lighting by electricity was divided by the lecturer into two principal parts—the methods of production of electric currents, and of conversion of the energy of those currents into heat at such a temperature as to be given off in radiations to which the eye was sensible. The laws known to connect together those phenomena called electrical, were essentially mechanical in form, closely correlated with mechanical laws, and might be most aptly illustrated by mechanical analogues. For example, the terms "potential," "current," and "resistance," had close analogues respectively in "head," "rate of flow," and "coefficient of friction" in the hydraulic transmission of power. Exactly as in hydraulics head multiplied by velocity of flow was power measured in foot-pounds per second, or in horse-power, so potential multiplied by current was power and was measurable in the same units. Again, just as water flowing in a pipe had inertia and required an expenditure of work to set it in motion, and was capable of producing disruptive effects if that motion were too suddenly arrested, so a current of electricity in a wire had inertia: to set it moving electromotive force must work for a finite time, and if arrested suddenly by breaking the circuit the electricity forced its way across the interval as a spark. Corresponding to mass and moments of inertia in mechanics there existed in electricity coefficients of self-induction. There was, however, this difference between the inertia of water in a pipe and the inertia of an electric current—the inertia of the water was confined to the water, whereas the inertia of the electric current resided in the surrounding medium. Hence arose the phenomena of induction of currents upon currents, and of magnets upon moving conductors—phenomena which had no immediate analogues in hydraulics.

The laws of induction were then illustrated by means of a mechanical model devised by the late Prof. Clerk Maxwell.

In the widest sense, the dynamoelectric machine might be defined as an apparatus for converting mechanical energy into the energy of an electrostatic charge, or mechanical power into its equivalent electric current through a conductor. Under this definition would be included the electrophorus and all frictional machines; but the term was used in a more restricted sense, for those machines which produced electric currents by the motion of conductors in a magnetic field, or by the motion of a magnetic field in the neighbourhood of a conductor. The laws on which the action of such machines was based had been the subject of a series of discoveries. Oersted discovered that an electric current in a conductor exerted force upon a magnet; Ampere that two conductors conveying currents generally exerted a mechanical force upon each other: Faraday discovered—what Helmholtz and Thomson subsequently proved to be the necessary consequence of the mechanical reactions between conductors conveying currents and magnets—namely, that if a closed conductor moved in a magnetic field, there would be a current induced in that conductor in one direction, if the number of lines of magnetic force passed through the conductor was increased by the movement; in the other direction if diminished. Now all dynamoelectric machines were based upon Faraday's discovery. Not only so; but however elaborate it might be desired to make the analysis of the action of a dynamo-machine, Faraday's way of presenting the phenomena of electromagnetism to the mind was in general the best point of departure. The dynamo-machine, then, essentially consisted of a conductor made to move in a magnetic field. This conductor, with the external circuit, formed a closed circuit in which electric currents were induced as the number of lines of magnetic force passing through the closed circuit varied. Since, then, if the current in a closed circuit was in one direction when the number of lines of force was increasing, and in the opposite direction when they were diminishing, it was clear that the current in each part of such circuit which passed through the magnetic field must be alternating in direction, unless indeed the circuit was such that it was continually cutting more and more lines of force, always in the same direction. Since the current in the wire of the machine was alternating, so also must be the current outside the machine, unless something in the nature of a commutator was employed to reverse the connections of the internal wires in which the current was induced, and of the external circuit. There were then broadly two classes of dynamoelectric machines—the simplest, the alternating-current machine, where no commutator was used; and the continuous-current machine, in which a commutator was used to change the connection with the external circuit just at the moment when the direction of the current would change. The theory of the alternate-current machine was then explained, and it was proved that two independently-driven alternate-current machines could not be worked in series, but that they might be worked in parallel circuit, and hence were quite suitable for distribution of electricity for lighting without the necessity of providing a separate circuit for each machine.

It was easy to see that, by introducing a commutator revolving with the armature, in an alternate-current machine, and so arranged as to reverse the connection between the armature and the external circuit just at the time when the current would

[1] Abstract of lecture delivered at the Institution of Civil Engineers on Thursday evening, April 5, by Dr. John Hopkinson, F.R.S., M.Inst.C.E.

© 1883 Nature Publishing Group

reverse, it was possible to obtain a current constant always in direction; but such a current would be far from constant in intensity, and would certainly not accomplish all the results obtained in modern continuous-current machines. This irregularity might, however, be reduced to any extent by multiplying the wires of the armature, giving each its own connection to the outer circuit, and so placing them that the electromotive force attained a maximum successively in the several coils. A practically uniform electric current was first commercially produced with the ring armature of Pacinotti, as perfected by Gramme. A dynamo-machine was not a perfect instrument for converting mechanical energy into the energy of electric current. Certain losses inevitably occurred. There was the loss due to friction of bearings, and of the collecting-brushes upon the commutator; there was also the loss due to the production of electric currents in the iron of the machine. When these were accounted for, there remained the actual electrical effect of the machine in the conducting wire; but all of this was not available for external work. The current had to circulate through the armature, which inevitably had electrical resistance; electrical energy must therefore be converted into heat in the armature of the machine. Energy must also be expended in the wire of the electromagnet which produced the field, as the resistance of this also could not be reduced beyond a certain limit. The loss by the resistance of the wires of the armature and of the magnets greatly depended on the dimensions of the machine. To know the properties of any machine thoroughly, it was not enough to know its efficiency and the amount of work it was capable of doing; it was necessary to know what it would do under all circumstances of varying resistance or varying electromotive force; and, under any given conditions, what would be the electromotive force of the armature? Now this electromotive force depended on the intensity of the magnetic field, and the intensity of the magnetic field depended on the current passing round the electromagnet and the current in the armature. The current then in the machine was the proper independent variable in terms of which to express the electromotive force. The simplest case was that of the series-dynamo, in which the current in the electromagnet and in the armature was the same, for then there was only one independent variable. The relation between electromotive force and current might be most conveniently expressed by a curve.

When four years ago the lecturer first used such a curve (since named by Deprez the "characteristic curve") for the purpose of expressing the results of his experiments on the Siemens dynamo-machine, he pointed out that it was capable of solving almost any problem relating to a particular machine, and that it was also capable of giving good indications of the results of changes in the winding of the magnets, or of the armatures of such machines The use of the characteristic curve was illustrated with reference to charging accumulators and Jacobi's law of electric transmission of power.

When the dynamo-machine was not a series-dynamo, but the current in the armature and in the electromagnet, though possibly dependent upon each other were not necessarily equal, the problem was not so simple. In that case there were two variables, the current in the electromagnet and the current in the armature; and the proper representation of the properties of the machine would be by a characteristic surface, of which a model was exhibited. By the aid of such a surface any problem relating to a dynamo-machine could be dealt with, no matter how its electromagnets and its armature were connected together. Of course in actual practice the model of the surface would not be used, but the projections of its sections.

The properties of a machine depended much upon its dimensions. Suppose two machines alike in every particular, excepting that the one had all its linear dimensions double that of the other. The electrical resistances in the larger machine would be one-half those of the smaller. The current required to produce a given intensity of magnetic field would be twice as great in the larger machine as in the smaller. The comparative characteristic curves of the two machines when driven at the same speed were shown in a diagram. The two curves were one the projection of the other, having corresponding points with abscisses in the ratio of one to two, and the ordinates in the ratio of one to four. At first sight it would seem that the work done by the larger machine should be thirty-two times as much as that which would be done by the smaller. Practically, however, no such result could possibly be attained for many reasons. First, the iron of the magnets became saturated, and consequently, instead of eight times the electromotive force, there would only be four times the electromotive force. Secondly, the current which the armature could carry was limited by the rate at which the heat generated in the armature could escape. Again, the larger machine could not run at so great an angular velocity as the smaller one. And lastly, since in the larger machine the current in the armature was greater in proportion to the saturated magnetic field than in the smaller one, the displacement of the point of contact of the brushes with the commutator would be greater. Shortly, the capacity of similar dynamo-machines was pretty nearly proportionate to their weight, that was to the cube of their linear dimensions; the work wasted in producing the magnetic field was directly as the linear dimensions; and the work wasted in heating the wires of the armature was as the square of the linear dimensions.

A consideration of the properties of similar machines had another important practical use. Mr. Froude was able to control the design of ironclad ships by experiments upon models made in paraffin wax. It was a much easier thing to predict what the performance of a large dynamo-machine would be, from laboratory experiments made upon a model of a very small fraction of its dimensions. As a proof of the practical utility of such methods, the lecturer stated that by laboratory experiments he had succeeded in greatly increasing the capacity of the Edison machines without increasing their cost, and with a small increase of their percentage of efficiency, remarkably high as that efficiency already was.

The electric properties of the electric arc were experimentally illustrated; in particular it was shown that the difference of potential between the carbons was nearly independent of the current.

When a current of electricity passed through a continuous conductor it encountered resistance, and heat was generated, as shown by Joule, at a rate represented by the resistance multiplied by the square of the current. If the current was sufficiently great, heat would be generated at such a rate that the conductor would become incandescent and radiate light. Attempts had been made to use platinum and platinum iridium as the incandescent conductor. But these bodies were too expensive for general use, and besides that, refractory though they were, they were not refractory enough to stand the high temperature required for incandescent lighting, which should be economical of power. Commercial success was not realised until very thin and very uniform threads or filaments of carbon were produced and inclosed in reservoirs of glass, from which the air was exhausted to the utmost possible limit. Such were the lamps made by Mr. Edison with which the Institution was temporarily lighted. The electrical properties of such a lamp were examined, and in particular it was shown that its efficiency increased and its resistance diminished with increase of current.

The building was lighted by about 230 lamps, each giving sixteen candles light, produced each by 75 Watts of power developed in the lamp. To produce the same sixteen candles' light in ordinary good flat-flame gas-burners, would require between 7 and 8 cubic feet of gas per hour, contributing heat to the atmosphere at the rate of 3,400,000 foot-pounds per hour, equivalent to 1250 Watts, or nearly seventeen times as much heat as the incandescence lamp of equal power.

At the present time, lighting by electricity in London must cost something more than lighting by gas. What were the prospects of reduction of this cost? Beginning with the engine and boiler, the electrician had no right to look forward to any marked and exceptional advance in their economy. Next came the dynamo, the best of these were so good that there was little room for economy in the conversion of mechanical into electrical energy; but the prime cost of the dynamo-machine was sure to be greatly reduced. Hope of considerably increased economy must be mainly based upon probable improvements in the incandescence lamp, and to this the greatest attention ought to be directed. It had been shown that marked economy of power could be obtained by working the lamps at high pressure, but then they soon broke down. In ordinary practice, from 140 to 200 candles were obtained from 1 horse-power, developed in the lamps, but for a short time he had seen over 1000 candles per horse-power from incandescence lamps. The problem, then, was so to improve the lamp in details, that it would last a reasonable time when pressed to that degree of efficiency. There was no theoretical bar to such improvements, and it must be remembered that incandescence lamps had only been articles of commerce for about three years, and already much had been done. If such an improvement were realised, it would mean that it

© 1883 Nature Publishing Group

would be possible to get five times as much light for a sovereign as could be done now. At present electric lighting would succeed commercially where other considerations than cost had weight. Improvements in the lamps were certain, and there was a probability that these improvements might go so far as to reduce the cost to one-fifth of what it now was. He left the meeting to judge whether or not it was probable, nay, almost certain, that lighting by electricity was to be the lighting of the future.

HARDENING AND TEMPERING STEEL

ONE of a series of lectures to the Liverymen and Apprentices of the Company of Cutlers of London was delivered on Thursday last by Prof. W. Chandler Roberts, F.R.S., "On some Theoretical Considerations connected with Hardening and Tempering Steel."

The Master of the Company, Mr. J. Thorne, presided, and the Lecturer observed that the phenomena with which they had to deal, although admittedly as interesting and remarkable as any in the whole range of metallurgy, are but little understood.

If the fact that steel can be hardened had not been known, the whole course of our industrial and even political history would probably have been widely different, and the dagger, which occupies so prominent a place in the armorial bearings of the City of London, would have represented a survival of implements made, not of steel, but of copper hardened with tin.

It has long been known that there are extraordinary differences between the properties of wrought iron, steel, and cast iron, but our knowledge that these differences depend upon the presence or absence of carbon is only a century old, for it was not until the year 1781 that Bergman, Professor in the University of Upsala, showed that wro ght iron, steel, and cast iron, when dissolved in certain acids, leave amounts of a graphitic residue, varying from $\frac{1}{10}$ to $2\frac{1}{2}$ per cent., which are essential to the constitution of these three varieties of metal. Bergman's work led many early experimenters, notably Clouet in 1796, to attempt to establish the importance of the part played by carbon, and Clouet converted pure iron into steel by contact at a high temperature with the diamond, which was the purest form of carbon he could command. Prof. Roberts said that this experiment had been repeated by many other observers with varying success, as in all the earlier work the furnace gases, which had not been excluded, might have converted the iron into steel without the intervention of the diamond. It remained for a distinguished Master of the Cutlers' Company, Mr. W. H. Pepys, to repeat Clouet's fundamental experiment under conditions which rendered the results unequivocal, by employing electricity as a source of heat. This experiment, which had been communicated to the Royal Society in 1815, was performed in the way Pepys had indicated.

It was then shown that in soft, tempered, and hardened steel respectively the carbon has a distinct "mode of existence," as is indicated by the widely different action of solvents on the metal in these three states.

The evidence as to whether carbon in steel is *combined* in the chemical sense, or is merely *dissolved*, was then considered at some length, special reference being made to the results obtained by various experimenters, from Berzelius and Karsten to Sir Frederick Abel of the War Department.

Prof. Roberts stated that the researches of Troost and Hautefeuille afforded strong evidence that in "white cast-iron" and steel the carbon is merely dissolved, a view which he adopted, as he did not consider it to be at all in opposition to the facts recently established by Sir Frederick Abel, who had shown that the carbon may be left by the slow action of solvents on soft steel as a carbide of iron.

The various physical, as distinguished from the chemical theories that had been propounded from the time of Réaumur, (1722) to that of Akerman (1879), to account for the "intimacy of the relation" of carbon and iron in hard as compared with soft steel, were then described at some length, and the remarkable experiments of Réaumur, who cooled steel slowly in a Torricellian vacuum in order to show that the absorption of gas did not take place during cooling, was illustrated.

In recent years much importance has been attached to the physical evidence as to the peculiar constitution of steel, and it has been shown that there is a remarkable relation between the amount of carbon contained in different varieties of steel and their electrical resistance. Some of the very interesting experiments of Prof. Hughes on this point were then exhibited and described, and Prof. Roberts concluded by saying that the value of the early work by Bergman and Réaumur had rather been lost sight of in recent discussions, Bergman's work being specially remarkable, as he attempted, by thermometric measurement, to determine the heat equivalent of the phlogiston he believed iron and steel to contain.

The importance of the degree of carburisation of steel from the point of view of its technical application was illustrated by reference to a series of curves, and it was incidentally mentioned that, in the case of the variety of steel used for the manufacture of coinage-dies, the presence of $\frac{1}{10}$ per cent. of carbon more or less than a certain standard quantity makes all the difference in the quality of the metal.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

OXFORD.—The new Board of the Faculty of Natural Science has issued its first list of lectures this term. The lectures are divided under the following heads:—Physics, Chemistry, Animal Morphology, Geology, and Botany. No lectures are scheduled this term under Mineralogy or Physiology.

In Physics Prof. Clifton lectures on "Instruments and Methods of Measurement employed in the Study of Optics." These lectures are given in the Clarendon laboratory, where practical instruction in Physics is given by the Professor, assisted by Messrs. Stocker and Heaton. At Christ Church Mr. Baynes lectures on Electrokinematics and Electrodynamics, and gives practical instruction on Electric and Magnetic Measurements. At Balliol Mr. Dixon gives a course of experimenta lectures on Elementary Heat and Light.

In Chemistry Dr. Odling lectures at the Museum on the Composition of Air and Water; Mr. Fisher lectures on Inorganic Chemistry; and Dr. Watts on the Cyanogen Series. At Christ Church Mr. Harcourt has a class for Quantitative Analysis, and Mr. Dixon a class for Gas Analysis.

In Animal Morphology Prof. Moseley lectures on Comparative Anatomy, and gives practical instruction to his class after each lecture; Mr. Hickson lectures on the Development of the Chick, Mr. Hatchett Jackson on Mammalian Osteology and the Principles of Embryology, Mr. Poulton on the Distribution of Animals, and Mr. Lewis Morgan on the Vertebrate Exoskeleton and on Human Osteology.

In Botany Mr. Chapman gives practical instruction on Vegetable Morphology at the Botanic Gardens.

In Geology Prof. Prestwich will give a series of lectures on Friday afternoons on the strata and fossils to be visited on his Saturday excursions.

On June 19 an examination will be held in common by Magdalen, Merton, and Corpus Christi Colleges for electing a Scholar in Physical Science at each College. At Merton and Corpus the chief subjects will be Chemistry and Physics.

Jesus College offers a Welsh Scholarship in Natural Science. The examination will be held on June 14.

Examinations for the degree of Bachelor of Medicine (both First and Second) will be held this term. Candidates are to send in their names before May 1.

CAMBRIDGE.—Prof. Huxley's Rede Lecture at Cambridge University will be given on June 12, at 3 p.m., in the Senate House. The subject is not yet announced.

Dr. Michael Foster leaves the Lectures on Elementary Biology for this term in the hands of Dr. Vines and Mr. Sedgwick, and will hold Catechetical Classes in Physiology for the Natural Sciences Tripos.

Dr. F. Darwin will give six Demonstrations on the Physiology of Plants (Growth, Movement, &c.) at the Physiological Laboratory on Saturdays at noon, beginning April 21.

Prof. Liveing will lecture on the Chemistry of the Heavenly Bodies, beginning May 1.

LONDON.—Mr. A. H. Keane has been appointed to the Hindustani Lectureship at University College.

THE Winter Session at the College of Agriculture, Downton, near Salisbury, ended on Monday, when the certificates and prizes were presented to the successful students by Archdeacon Sanctuary. The certificate of membership, obtainable on examination after completion of the two years' course of study, was granted to Mr. Arthur Herbert Kerr, Crookham, Farnham,

© 1883 Nature Publishing Group